

**PANONYCHUS CITRI (ACARI: TETRANYCHIDAE)
ON ORNAMENTAL SKIMMIA IN OREGON,
WITH ASSESSMENT OF PREDATION BY NATIVE
PHYTOSEIID MITES**

P. D. PRATT AND B. A. CROFT

Department of Entomology Oregon State University
Corvallis, Oregon 97331-2907

Abstract.—In the U.S., *Panonychus citri* (McGregor) (citrus red mite) typically occurs on citrus in semi-tropical regions of California, Texas, and Florida. Its occurrence in the Willamette Valley, Oregon and its association with an ornamental host plant *Skimmia japonica* Thunberg are reported. To assess potential biological control of this pest, excess amounts of *P. citri* from *S. japonica* were provided to confined native predaceous phytoseiid mites of several species, including *Amblyseius andersoni* Chant, *Metaseiulus occidentalis* (Nesbitt), *Neoseiulus fallacis* (Garman), and *Typhlodromus pyri* Scheuten. *Neoseiulus fallacis* was also presented either with no food or with *Tetranychus urticae* (Koch) for comparison with *P. citri*. Survivorship, activity, cumulative oviposition per female per d, and cumulative immature production of the predaceous mites were assessed every 24 hours for seven days. Survival and oviposition by adult females and production of immatures by *N. fallacis* were higher with *T. urticae* vs. *P. citri*, but activity of adult females and survival of immatures were about the same with either prey. All measured attributes of *N. fallacis* were at lower levels without prey than with *P. citri*, except activity (greater). Adult females of *T. pyri*, *M. occidentalis* and *N. fallacis* demonstrated greater survival and oviposition rates than did adult females of *A. andersoni*. When with *P. citri*, *M. occidentalis* and *N. fallacis* had greater survival of immatures than did *T. pyri* or *A. andersoni*. When introduced to the host plant *S. japonica*, *N. fallacis* significantly reduced the densities of *P. citri* in five weeks when compared to pest mite populations lacking the predator.

Key Words.—Acari, *Panonychus citri*, *Skimmia japonica*, ornamental plant, Phytoseiidae, *Neoseiulus fallacis*, secondary plant chemicals.

Spider mites are pests in ornamental nurseries (Weidhaas 1979, Mizell & Short 1992), where they can reduce growth and can render plants unsightly and unmarketable (Schiffauer & Mizell 1988, Smitley & Peterson 1991). Although the ornamental plant *Skimmia japonica* Thunberg, produces chemicals (e.g., furanocoumarins) that deter feeding by some arthropods (Tanaka et al. 1985, Escoubas et al. 1993), two spotted spider mite (*Tetranychus urticae* Koch) commonly infest this plant. In 1996-1997, samples of *S. japonica* were found to harbor high levels of another spider mite, *Panonychus citri* (McGregor) (citrus red mite), in nurseries and outdoor landscapes in western Oregon (PDP, unpublished data). *Panonychus citri* infests citrus plants of the subfamily Aurantioideae, but plants in the Tod-dalioideae, the subfamily of *S. japonica* (Mabberley 1987) were not previously recorded as hosts. Previously known distributions of *P. citri* in the U.S. include semitropical parts of California, Texas, and Florida (Jeppson et al. 1975, French & Hutchinson 1980), but not Oregon.

Panonychus citri and associated predaceous phytoseiid mites occurring on citrus are well documented (McMurtry 1985), but they do not include species that are commonly found in western Oregon (Hadam et al. 1986). For example, *Euseius* spp. are most common on citrus but they are of semi-tropical and tropical distribution (McMurtry & Croft 1997). The combination of an introduced pest on

a non-native ornamental caused us to question whether the most common native phytoseiids of western Oregon, including *Amblyseius andersoni* Chant, *Metaseiulus occidentalis* (Nesbitt), *Neoseiulus fallacis* (Garman), and *Typhlodromus pyri* Scheuten (Hadam et al. 1986), could suppress *P. citri* populations. *Neoseiulus fallacis* is widely released on ornamentals and other crops to control spider mites (McMurty & Croft 1997). Our objectives in this study were: 1) to assess the ability of *N. fallacis* to reproduce and develop on *P. citri* compared to a highly preferred prey, *T. urticae* and similar abilities of *A. andersoni*, *M. occidentalis*, and *T. pyri*, on *P. citri*; and 2) to assess whether *N. fallacis* could suppress *P. citri* on *S. japonica* in an ornamental production nursery.

METHODS AND MATERIALS

Identification of P. citri Infesting S. japonica.—Spider mites found on *S. japonica* were monitored at three ornamental nurseries and two landscape sites in western Oregon in 1996 and 1997. Nurseries were near Salem, Oregon and landscapes were near Salem and on the campus of Oregon State University in Corvallis. Mites were sampled by taking 100 leaves at random from 20 plants located in an X pattern across 5–10 beds. Mites in landscapes were sampled by removing 20–50 leaves at random from each of 10 *S. japonica* plants in a hedgerow. Leaves were placed in a cooler, transported to the laboratory, and mites were examined with a 40 \times microscope. An unidentified spider mite species was found at all sites in 1996 and 1997. Adults of both sexes were mounted on glass slides and identified by J. A. McMurtry and G. W. Krantz of Oregon State University. Specimens were placed in the acarology collection of Oregon State University.

Feeding Tests of Four Predatory Mites.—Laboratory cultures of *A. andersoni*, *N. fallacis*, and *T. pyri* were originally collected from agricultural crops in the Willamette Valley, Oregon (Hadam et al. 1986). *Metaseiulus occidentalis* was collected from an apple orchard near Hood River, Hood River, Oregon (Croft et al. 1992). These cultures have been maintained for five years or more with yearly additions from field-collected specimens. Cultures were held at $25 \pm 5^\circ\text{C}$, 16:8 L:D, and 75–95% RH, and mites were fed mixed life stages of *T. urticae* three times per week. Prior to the experiment, all predatory mites were held without food for 24 h to produce similar levels of hunger.

Tests for *A. andersoni*, *M. occidentalis*, *N. fallacis*, and *T. pyri* against *P. citri* were conducted simultaneously on 2.5×2.5 cm arenas constructed of waterproof paper and replicated eight times per species (Monetti & Croft 1997). Three adult female mites of a single species of about the same age were transferred to each arena. Excess mixed life stages of *P. citri* were provisioned every 24 h and arenas were placed in a 1×2 m environmental chamber at $25 \pm 1^\circ\text{C}$, $80 \pm 10\%$ RH, and 16:8 L:D for 7 day. *Neoseiulus fallacis*, the predator of greatest interest, was also fed the optimal (with respect to reproduction) prey *T. urticae* or given no food. Arenas were briefly removed from chambers every 24 h to assess survivorship, activity (ambulation in the arena), cumulative oviposition per female per day, and cumulative production of immatures (larvae, protonymphs, deutonymphs). An index for survivorship of immatures was calculated on day 3–7 by dividing the number of immatures by the number of eggs present two days prior to the sampling of immatures (Croft et al. 1998). Means of each measured attribute were analyzed by analysis of variance (ANOVA) and Tukey's HSD.

Biological control P. citri by N. fallacis on S. japonica in a nursery.—Preliminary feeding tests showed that *N. fallacis* would feed, reproduce, and develop on *P. citri*, but at lower rates than when provisioned with *T. urticae*. Because *N. fallacis* is often inoculated into crops, we were interested in its ability to control *P. citri* on *S. japonica*. In 1997, 10 three year old *S. japonica* ('Female') plants were potted in 3.8 liter containers. Plants were inoculated with *P. citri* to ensure uniform levels per plant. A randomized design was used within a single irrigation system and treatments were either release of three adult female *N. fallacis* per plant or no release (control). On 2 Jul, *P. citri* averaged 12 ± 3 (all life stages) per leaf and three adult female *N. fallacis* were released into the canopy of each *S. japonica* plant (Strong & Croft 1995). To estimate population densities, five leaves were randomly selected per plant (without replacement) every week for five weeks. Leaves were placed in a cooler, taken to the laboratory, and processed within two h. A 40 \times microscope was used to count mites. To adjust for sampling the same populations over time, data were analyzed by repeated measures ANOVA (von Ende 1993).

RESULTS

Identification of P. citri on S. japonica.—As noted, specimens of the unknown pest mite infesting *S. japonica* in western Oregon were identified as *P. citri*. Routine sampling in both 1996 and 1997 indicated that *P. citri* was infesting *S. japonica* at all five locations that were sampled, suggesting that *P. citri* successfully overwinters in western Oregon. Although not documented to species, nursery growers had been aware of this pest mite and the damage it was causing for about five yrs (J. Mellot, personal communication).

Feeding Tests of Predatory Mites.—When comparing food types of *N. fallacis*, survivorship was significantly different when mites were provisioned with *T. urticae* > *P. citri* > starvation treatments ($P < 0.05$). Starvation increased the activity of *N. fallacis* but activity rates were similar when held with either prey mite ($P < 0.05$, Table 1). *Neoseiulus fallacis* produced more eggs and immatures per d when held with *T. urticae* vs. *P. citri* ($P < 0.05$), and egg production nearly ceased when predators were starved (Table 1). Immature survival was not different when *N. fallacis* was held with *P. citri* vs. *T. urticae*, but it was lower for the starvation treatment of *N. fallacis* ($P < 0.05$).

Survivorship of mites fed on *P. citri* was similar for *N. fallacis*, *M. occidentalis*, and *T. pyri*, but significantly lower for *A. andersoni* ($P < 0.05$). Survivorship for all predators feeding on *P. citri* was <73% (Table 1). Activity did not differ among the four mite species ($P < 0.05$). Oviposition per d was similar for *N. fallacis*, *M. occidentalis*, and *T. pyri*, but lower for *A. andersoni* ($P < 0.05$). *Neoseiulus fallacis* and *M. occidentalis* produced more immatures than *A. andersoni* ($P < 0.05$), but immature production did not differ among *T. pyri* and the other three phytoseiids. The index of immature survival was similar among all four predaceous mites when provisioned with *P. citri*.

Biological Control of P. citri by N. fallacis in an Outdoor Production Nursery.—*Neoseiulus fallacis* significantly reduced *P. citri* on release plants of *S. japonica* when compared to control plants over five sample dates ($P = 0.0001$; $df = 1,38$; $F = 43.42$). In control plants, *P. citri* increased to 35 (± 9) mixed life stages per leaf before decreasing to 15 (± 5) at the end of the test (Fig. 1).

Table 1. Survival, activity, oviposition and immature production of *Neoseiulus fallacis*, *Metaseiulus occidentalis*, *Typhlodromus pyri*, and *Amblyseius andersoni* when held with unlimited numbers of prey over 7 days.

Predator mite	Prey	Survivorship ^a Mean \pm SD	Activity ^b Mean \pm SD	Egg/female/day ^c Mean \pm SD	IMM./female/day ^d Mean \pm SD	Index ^e Mean \pm SD
<i>Neoseiulus fallacis</i>	<i>T. urticae</i>	1.00 \pm 0.036a ^g	0.174 \pm 0.112a	2.854 \pm 0.399a	2.867 \pm 3.429a	1.036 \pm 0.1566a
	Starvation	0.363 \pm 0.076c	0.571 \pm 0.132b	0.071 \pm 0.099c	0.0 \pm 0.0d	0.0 \pm 0.0b
	<i>P. citri</i>	0.729 \pm 0.132b	0.092 \pm 0.089a	1.262 \pm 0.246b	1.210 \pm 0.469b	1.022 \pm 0.450a
<i>Metaseiulus occidentalis</i>	<i>P. citri</i>	0.701 \pm 0.098b	0.170 \pm 0.116a	1.499 \pm 0.474b	1.388 \pm 0.829b	0.775 \pm 0.517a
<i>Typhlodromus pyri</i>	<i>P. citri</i>	0.667 \pm 0.132b	0.128 \pm 0.097a	1.607 \pm 0.6986b	0.982 \pm 0.456bc	0.575 \pm 0.293ab
<i>Amblyseius andersoni</i>	<i>P. citri</i>	0.315 \pm 0.137c	0.054 \pm 0.059a	0.333 \pm 0.196c	0.384 \pm 0.484dc	0.765 \pm 1.018ab
	P-value ^f	<0.0001	<0.0001	<0.0001	<0.0001	=0.0028

^a Percent female survival after 7 days in arenas.

^b Percent female activity (ambulation) within arena per 1 min observation per day.

^c Cumulative number of eggs produced per female per day.

^d Cumulative number of immatures produced per female per day.

^e Survivorship of immatures calculated on day 3–7 by dividing the number of immatures present by the number of eggs present 2 days prior to count.

^f Means of all tests were analyzed simultaneously by ANOVA, df = 5, 42.

^g Means followed by different letters are significant at $\alpha = 0.05$ (Tukey's HSD).

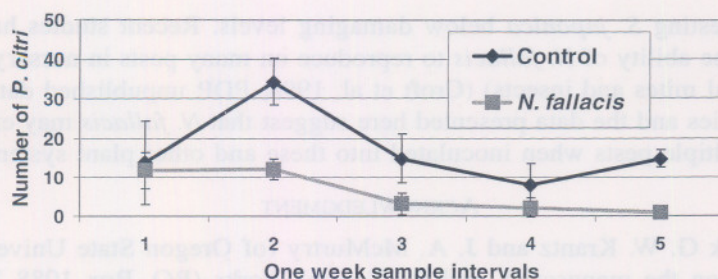


Figure 1. Population levels of *P. citri* on *S. japonica* 'Female' after release of the predatory mite *N. fallacis* on week one.

The decrease in pest mites in control plants may have been due to declining vigor or host suitability. In plants with *N. fallacis*, spider mites were reduced to $1.4 (\pm 2)$ per leaf 3 weeks after the release of predators and remained low thereafter.

DISCUSSION

We report establishment of *P. citri* on the ornamental, *S. japonica*, in western Oregon. Although this pest has overwintered successfully in this region, its long term survival potential over a cold winter is open to speculation. Our results suggest that *P. citri* can feed and reproduce on *S. japonica*, a plant that is only distantly related to citrus. Physiological effects on *P. citri* when feeding on *Skimmia* are unknown.

Feeding tests suggest that *N. fallacis* will survive and reproduce on *P. citri*, but it is more adapted to feed on *T. urticae*. These results are similar to those from other studies that compared predation of *N. fallacis* on *Panonychus ulmi* (McGregor) vs. *T. urticae* (Croft et al. 1998). Both assessments indicated that *N. fallacis* may prefer species of *Tetranychus*, which are prone to spin more copious webbing than other spider mite species. These data confirm the life type classification for *N. fallacis* as a Type II selective predator that prefers *Tetranychus* over other tetranychid genera (Croft et al. 1998, Croft & McMurtry 1997). Our studies show that at least three of the four predator species could feed, reproduce and develop on *P. citri*, but survivorship in some was less than maximal. One explanation for low survival of *N. fallacis* may be the ability of *P. citri* to sequester antifeedants of *S. japonica* (Escoubas et al. 1993, Tanaka et al. 1985). Reduced survival was surprising considering that all four species are effective biological control agents of the related *P. ulmi* (Croft et al. 1998, McMurtry & Croft 1997). Overall, life history data should be viewed with caution, because searching by predators on paper arenas might be quite different from searching on leaves in nature.

Activity was similar among all four predatory mites when given *P. citri* and like *N. fallacis* when held with *T. urticae*, suggesting that each predator probably was arrested by *P. citri* (Croft et al. 1998, Monetti & Croft 1997). *Amblyseius andersoni* had the lowest level of activity, but this measurement was affected considerably by increased mortality and morbidity of the predator. Although *M. occidentalis* and *T. pyri* demonstrate potential as predators of *P. citri*, more studies are needed to determine if these predators can maintain *P. citri* at low levels under actual field conditions. In limited field tests, *N. fallacis* was able to suppress

P. citri infesting *S. japonica* below damaging levels. Recent studies have demonstrated the ability of *N. fallacis* to reproduce on many pests in nursery systems (i.e., several mites and insects) (Croft et al. 1998, PDP, unpublished data). These earlier studies and the data presented here suggest that *N. fallacis* may effectively control multiple pests when inoculated into these and other plant systems.

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